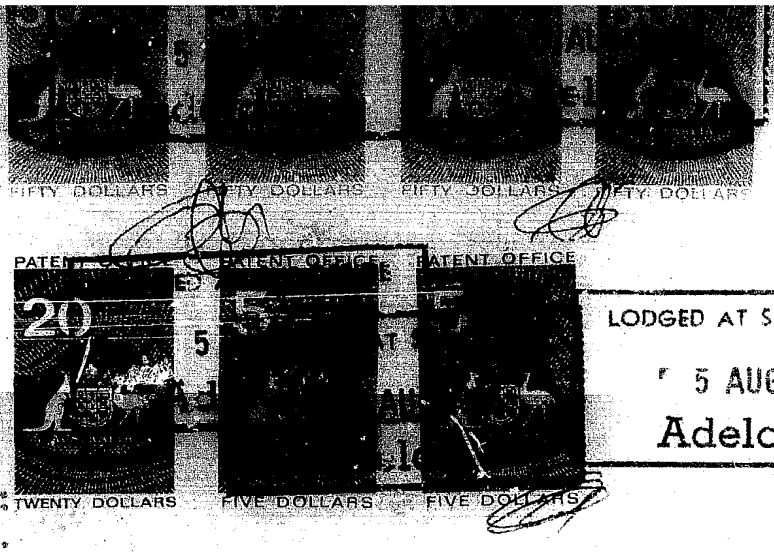

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5 AUG 1985
Adelaide

COMMONWEALTH OF AUSTRALIA
Patents Act 1952 - 1966

CONVENTION APPLICATION FOR A PATENT

INSTRUCTIONS

Full name(s) of applicant(s).

~~I~~/We PM MINERAL LEACHING TECHNOLOGIES INC., a Canadian Corporation,

Address(es) of applicant(s).

of Suite 107B, Discovery Park, 3700 Gilmore Way, Burnaby, British Columbia, Canada V5G 4M1

hereby apply for the grant of a Patent for an invention entitled

Title of invention

"BIOLEACHING PROCESS"

which is described in the accompanying complete specification. This application is a Convention application and is based on the following application or applications for a patent or patents or similar protection made in the following country or countries:

Country(ies) in which basic application(s) was/were made and date and number(s) of basic application(s).

in U.S.A. on 26th November 1984 No. 675,098

~~in~~ ~~on~~ ~~19~~ ~~No~~

~~in~~ ~~on~~ ~~19~~ ~~No~~

~~My~~/Our address for service is care of R. K. MADDERN and ASSOCIATES, Patent Attorneys. ~~97~~ King William Street, Adelaide, South Australia 5000.
345

Dated this 5th day of August 19 85

May be signed by Australian Patent Attorney.

PM MINERAL LEACHING TECHNOLOGIES INC.
By their Patent Attorneys
R.K. MADDERN & ASSOCIATES

R.S. CATT

To: The Commissioner of Patents
Commonwealth of Australia.

APPLICATION TO BE IN PERSONAL NAMES UNLESS BY BODIES INCORPORATED BY LAW.

Person. Nicht zutreffende Teile müssen gestrichen werden.

COMMONWEALTH OF AUSTRALIA

Patents Act 1952-1966

DECLARATION IN SUPPORT OF A CONVENTION APPLICATION FOR A PATENT OR PATENT ADDITION

In support of the Convention application made by

PM MINERAL LEACHING TECHNOLOGIES INC.

for a patent/~~patent of addition~~ for an invention entitled

BIOLEACHING PROCESS

I/~~We~~ ALBERT BRUYNESTEYN

of 2175 Greylynn Crescent, North Vancouver, British Columbia, Canada

do solemnly and sincerely declare as follows:—

1. ~~I am/We are the applicant(s) for the patent/patent of addition~~
(or, in the case of an application by a body corporate)
~~(oder: im Falle einer Anmeldung einer juristischen Person)~~

1. I am/~~We are~~ authorized by the abovementioned applicant(~~s~~) for the patent/~~patent of addition~~ to make this declaration on its/~~their~~ behalf.

2. The basic application(~~s~~) as defined by section 141 of the Act was/~~were~~ made in the following country or countries on the following date(~~s~~) by the following applicant(~~s~~) namely:—

in the United States	on	November 26,	19 84
by ALBERT BRUYNESTEYN			
~~in~~	~~on~~		~~19~~
~~by~~			
~~in~~	~~on~~		~~19~~
~~by~~			

3. I am/~~We are~~ the actual inventor(~~s~~) of the invention referred to in the basic application
~~(or, where a person other than the inventor is the applicant)~~
~~(oder wenn der Anmelder eine andere Personals als der Erfinder ist)~~

and the facts upon which the Applicant is entitled to make the application are as follows:-

~~of~~ The Applicant is the Assignee of the actual inventor.

~~is/are the actual inventor(s) of the invention and the facts upon which the applicant(s) is/are entitled to make the application are as follows:—~~

4. The basic application(~~s~~) referred to in paragraph 2 of this Declaration was/~~were~~ the first application(~~s~~) made in a Convention country in respect of the invention the subject of the application.

Declared at North Vancouver, British Columbia, Canada this 5th day of MARCH 19 85.

PM MINERAL LEACHING TECHNOLOGIES INC.

By: A. Bruynesteyn
President

The Commissioner of Patents,
Commonwealth of Australia.

(12) AUSTRALIAN PATENT ABSTRACT
(19) AU (11) AU-A-45769/85

(54) BIOLEACHING FE PRIOR TO GOLD AND SILVER RECOVERY FROM SULPHIDE ORES

(71) PM MINERAL LEACHING TECHNOLOGIES INC.
(21) 45769/85 (22) 5.8.85 (24) 26.11.84
(31) 675098 (32) 26.11.84 (33) US
(43) 5.6.86
(51)4 C22B 11/04 C22B 3/00
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(74) MA
(57) Claim

1. A process for leaching gold and silver from sulfide bearing ores of gold and silver the method comprising:

contacting the ore with a sulfide oxidizing bacteria in a leaching suspension having a pH of not less than 0.5;

maintaining the temperature in the range 5° to 40°C;

maintaining the pH in the range about 0.5 to 2.8;

separating solids from the leaching liquid; and

extracting gold and silver from the final solids content.

.../2

6. A process as claimed in claim 5 in which the partial neutralization is carried out in such a way that the pH does not rise above 2.8 causing any contained ferric iron in the leaching liquid to precipitate as basic ferric sulfate and any arsenic and antimony present in the ore, and oxidized by the ferric iron to arsenate during the biological leach, to precipitate as ferric arsenate.

12. A process as claimed in claim 1 in which the sulfide oxidizing bacteria is Thiobacillus ferrooxidans.

16. A process as claimed in claim 1 in which silver and gold is removed from the solids produced by extraction with cyanide, thiourea, thiosulfate, or chloride.

Form 10

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952-62

COMPLETE SPECIFICATION

(ORIGINAL)

FOR OFFICE USE:

Application Number: Class Int. Class
Lodged:

Complete Specification Lodged:
Accepted:
Published:

Priority:

Related Art:

US 769/85

TO BE COMPLETED BY APPLICANT

Name of Applicant: PM MINERAL LEACHING TECHNOLOGIES INC.

Address of Applicant: Suite 107B, Discovery Park, 3700 Gilmore Way, Burnaby, British Columbia, Canada V5G 4M1

Actual Inventor: ALBERT BRUYNESTEYN

Address for Service: care of R.K. MADDERN & ASSOCIATES, 345 King William Street, Adelaide, South Australia, 5000

Complete Specification for the invention entitled:

"BIOLEACHING PROCESS"

The following statement is a full description of this invention, including the best method of performing it known to ~~me~~ us .

FIELD OF THE INVENTION

This invention relates to a process for leaching gold and silver from sulfide bearing ores of the metals. In particular the process is a bioleaching process, using bacteria.

DESCRIPTION OF THE PRIOR ART

Biological extraction using microorganisms to oxidize sulfidic minerals is well known. The biological oxidation by the microorganisms releases the metals chemically bound or held captive in the substrate crystalline structure thus facilitating their extraction. The biological extraction has been shown to be a substantial improvement over conventional processes. It allows treatment of lower grade and more complex ores and it does so without environmental damage. Of particular importance is that the process can turn uneconomical deposits into commercially useful sources of minerals.

Many ore bodies in North America are hydrothermal. As a result the gold and silver values contained are often in association with sulfide minerals such as pyrite and arsenopyrite and, in general, contaminated with arsenic and antimony sulfides. Gold associated with sulfides can occur in two variations. It may be free or coated on the outside of the sulfide mineral or it may be in close association with the sulfides. In the latter

case the gold is often held captive inside the sulfide crystals and is not accessible to chemical lixiviants, such as cyanide solution.

When the gold is not held captive it can normally readily be recovered by treatment with a cyanide solution, a process of some considerable antiquity. However even then some sulfides, particularly pyrrhotite, tend to decompose in solution, causing excess consumption of cyanide reagent and at the same time inhibiting gold extraction. When the gold is held captive inside the sulfide crystals extraction by cyanide is not possible as the reagent cannot make direct contact with the gold. In these cases the ore is called refractory and it is necessary to use high temperature treatment, for example roasting and smelting, or expensive high pressure leaching techniques, to break down the sulfide and liberate the gold for subsequent extraction by the cyanide. As most ores do not contain sufficient quantities of gold to justify economic treatment by smelting or roasting it is normal to upgrade the sulfides by froth flotation first.

Gold ores containing arsenic and antimony are considerably more difficult to treat because the arsenic and antimony content usually makes the ore refractory to treatment by direct cyanide or by amalgamation. These ores must be milled and their gold values concentrated by

flotation. The resulting concentrates are roasted to break down the sulfide before cyanide treatment can be applied. Extensive pollution control, necessary with such toxic chemicals, adds substantially to the processing cost of roasting plants and most smelters will not accept any concentrate that contains more than 2 to 3% combined arsenic and antimony.

Thus when an ore contains precious metals captive in sulfide crystals, and particularly when arsenic and antimony sulfide are present, the number of possible treatment processes is limited and the processes expensive. The treatment cost normally increases rapidly with increasing sulfur and arsenic content.

Refractory ores are often treated by direct cyanide to recover the free and readily available precious metals with the operator accepting the partial extraction normally associated with this type of treatment as well as the normally high cyanide consumption. However in such cases the captive precious metals are lost to the tailings and no attempt has been made to recover them.

The oxidation of sulfide minerals by bacteria, particularly the bacterium Thiobacillus ferrooxidans is well known and has received excellent acceptance in the mining industry. It has found particular application in the copper industry where the bacteria are used exten-

sively for the extraction of copper from low grade waste materials. The bacteria has also found application in the extraction of uranium from pyritic ores.

SUMMARY OF THE INVENTION

The present invention provides a process for leaching gold and silver from sulfide bearing ores of these metals. The process may be carried out either in tanks, usually with agitation, or in so-called heap leaching, in which a solution of the bacteria is applied to a heap or mound of the ore to be extracted.

More specifically the present invention is a process for leaching gold and silver from sulfide bearing ores of gold and silver, the method comprising contacting the ore with a sulfide oxidizing bacteria in a leaching suspension having a pH of not less than 0.5; maintaining the temperature in the range 5° to 40°C; maintaining the pH in the range about 0.5 to 2.8; separating solids from the leaching liquid; and extracting gold and silver from the final solids content.

The pH of the process is important. The sulfuric acid developed by oxidation of the sulfide by the bacteria may be used to maintain the pH in the defined range. However it is desirable to include partial neutralizing of sulfuric acid to maintain the pH in the desired range. In a preferred embodiment this may be done by removing continually part of the leaching suspen-

sion, adding to the extracted part a base to control pH, typically lime, then returning the removed leaching suspension to the biological reactor. Preferably the solids removed from the leaching suspension in this way are separated on their removal. The solids are returned to the leaching suspension and the liquids are then partially neutralized, again typically by lime, to control the pH. Partial neutralization should be carried out in such a way that the pH does not rise above 2.8. As a result of this pH restriction, contained ferric iron in the leaching liquid is precipitated as basic ferric sulfate (jarosite). Any arsenic present in the process is oxidized by the ferric iron to arsenate during the biological leach and then precipitated as ferric arsenate during the partial neutralization process. It should also be noted that partial neutralization will inhibit buildup of any metal that may inhibit the bacteria.

In a preferred embodiment the process is carried out in a series of steps, for example 4. Typically pH control is necessary in the first two or three steps for high sulfide concentrates and, again, the pH control is desirably carried out as indicated above, that is by extracting a portion of the leaching solution and controlling the pH by adding a base, typically lime, to the liquid. However the control of the pH in each

step is desirable to precipitate metals, such as ferric iron and arsenic, that may inhibit the bacteria.

The desired gold and silver may be removed from the final solids produced by chemical extraction. Typically the extraction of the gold and silver may be carried out by a cyanide leach, but extraction with thiourea, thiosulfate and chloride may also be used.

As indicated generally above the preferred oxidizing bacteria is Thiobacillus ferrooxidans.

DRAWINGS

A flow diagram of a typical process according to the present invention is shown in the accompanying drawing.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The drawing shows a hopper 2 to receive ore concentrate which is passed to a slurry tank 4. As indicated schematically the slurry tank 4 is provided with a conventional agitating means in the form of a rotor 6.

From the slurry tank the slurry is pumped into the first biological reactor 8 of four biological reactors 8, 10, 12 and 14. The biological reactors are operated ideally at 30 - 40°C temperature and at atmospheric pressure.

In the biological reactors the biological oxidation of the ore is carried out. Typically the reactors 8, 10, 12 and 14 are provided with a means for agitation

which may be supplied by motor driven turbine or propellers or by air sparging.

From the first three reactors 8, 10 and 12 leach solutions are extracted into solids/liquids separators 14. The separated solids are passed back to the reactors 8, 10 and 12 via the pipeline 16. The liquids are fed to a neutralizing tank 18 fitted with an agitator 20. A base, typically lime, is added from tank 22 in predetermined manner to control the pH. Typically the pH is controlled in such a manner that it does not exceed 2.8. Under these circumstances arsenic or antimony, dissolved and oxidized to its highest valency state during the leaching process by the available ferric iron, then reacts with the ferric iron to form insoluble ferric arsenate or ferric antimonate. Iron is also removed at this stage as basic ferric sulfate. These solids, which are separated in solids/liquid separator 24 are environmentally acceptable and following liquid/solid separation are fed through line 26 to line 28 leading to a settling or tailing pond.

Liquid from the liquid solid separator 24 is returned via line 30 to the reactors 8, 10 and 12. Generally the last reactor 14 does not need a solids/liquid separator 14 nor does it receive recycled liquid through line 30. It is also possible to run the system with other biological reactors not communicating

with a solids/liquid separator 15 or with line 30. However it is preferred that at least the first two biological reactors 8 and 10 should have solids/liquid separation and recirculation.

When the reaction is completed in reactor 14 the contents of the reactor are fed through line 32 to solids/liquid separator 34. The solids are separated and fed to a washer 36 having inlet 38 for water and inlet 40 for lime. The lime adjusts the pH and the solids are then fed as a slurry to a conventional cyanide extraction plant 42. The plant 42 is provided with an agitator 44.

Liquid from the washer 36 is returned through line 46 to line 48 and combined with liquid from the solids/liquid separator 34. The combined liquids are fed to neutralizing tank 50, provided with agitator 52, and there mixed with lime fed from lime tank 54. The neutralized product from the neutralizing tank 50 is fed to solids/liquid separator 56. The solids from the separator 56 are fed into line 28 to go to tailings and the liquid is returned to the slurry tank 6 through line 58.

EXPERIMENTAL RESULTS

Experimental extractions were carried out on a number of ore samples from various mines. Seven samples of various refractory ores or concentrates were subjected to a preliminary test merely to determine if the minerals in these samples were amenable to the biological leaching

process of the present invention. The results of the test show that all minerals tested responded favourably and that the improvement in extraction obtained were impressively high, particularly bearing in mind that the tests were not designed to yield maximum extraction but only to prove that the bacteria could utilize the contained sulfides substrate on which to live.

It is considered particularly interesting that strains of the bacteria could be developed which were capable of oxidizing tetrahedrite as well as stibnite and arsenopyrite. These specific strains were developed by maintaining cultures of T. ferrooxidans in a 10% weight by volume pulp density as the substrate in question for up to 3 months while, during that period, the pH of the suspension was kept below 2.5 with the addition of sulphuric acid when appropriate. The commercial consequences of this capability is significant. During the biological leach these potential contaminants are oxidized to their highest valence and during partial neutralization are combined with available ferric iron to form environmentally acceptable salts, that is salts that can be fed to the tailings without undue concern for environmental hazard.

The following table sets out the results achieved. The heading "Biotreated" means treated according to the present invention.

ONCEN-RATE	DESCRIPTION	HEAD ASSAY Au (g/tonne)	Ag	S (%)	EXTRACTION (%) Untreated Au	Ag	Biotreated Au	Ag
1.	Pyrite Arseno-pyrite	986	558	25.8	67.4	39.6	97.8	90.4
2.	Pyrite Arseno-pyrite	163	303	9.9	57.2	26.5	70.7	66.4
3.	Arseno-pyrite Stibnite	196	38	16.0	76.3	62.4	95.6	74.7
4.	Pyrite	-	824	16.0		47.2	-	85.7
5.	Tetrahe-drite Enargite Arseno-pyrite	-	5,044	30.0	-	<1 0	-	78.6
6.	Pyrite Arseno-pyrite	18	28	13	80.3	92.7	94.0	98.0
7.	Pyrite Pb/Zn/Cu	-	6,658	15.8	-	40.0	-	87.8

A typical test as carried out on a concentrate #7 is described.

SUMMARY

- The concentrate tested contained 6,658.1 grams of silver per metric tonne, as well as 0.206 g/T of gold.
- Only the behaviour of the silver in the concentrate

was followed in this initial test.

- A strain of the bacterium Thiobacillus ferrooxidans was developed, capable of oxidizing the metal sulfides in the concentrate.
- The process improved silver extraction from 26.8% to 87.8% through the biological oxidation of 57.8% of the available iron sulfides.
- Solution assays suggest that 68.3% of the copper and 64.9% of the zinc were solubilized during the leach.

EXPERIMENTAL CONDITIONS

BIOLOGICAL LEACH TEST

The biological leach tests were carried out at 10% (500 g) solids in a 5 L, turbine agitated baffled tank at 35° C. Air enriched with carbon dioxide (1% of carbon dioxide in air) was sparged underneath the turbine to provide the dissolved oxygen and carbon dioxide necessary for bacterial growth. The leach solutions contained appropriate nutrients to allow for sustained bacterial growth and, prior to inoculation with a specially grown strain of bacteria, the pH of the leach suspension was adjusted to 2.2 with dilute sulphuric acid.

The progress of the leach was followed by periodically measuring the soluble iron concentrations and pH of the solution. The leach residue was filtered and the solids washed and treated by cyanidation for precious metal extraction.

CYANIDE LEACH TEST

Untreated head concentrate and the leach residue were leached in excess cyanide using standard 24 h bottle roll procedures. Sodium hydroxide was added to maintain protective alkalinity. Excess cyanide in the final cyanide leach solution was determined by silver nitrate titration.

RESULTS AND DISCUSSION

SAMPLE ASSAYS

The head sample of the concentrate tested assayed as follows:

Fe	7.06%	Pb	18.0%	
Cu	1.06%	Insol.	27.1%	
S	15.8 %	Au	0.206	g/tonne
Zn	10.0%	Ag	6658.1	g/tonne

The leach on the concentrate followed a typical progress, with the first 80 h used for the bacterial strain to adapt to the concentrate, following which the oxidation of the sulfides started, as witnessed by the solubilization of the iron. It was not intended to determine the optimum rate of iron solubilization from the results of this test, and more complete tests will be conducted to establish the kinetics of the leach. Previous experience with other concentrates does suggest that the retention time for a 20% pulp leach suspension will be in the 2-5 day range.

Upon termination of the leach, the pregnant solution contained 4.26 g/L Fe, 1.10 g/L Cu and 6.36 g/L Zn, indicating Fe, Cu and Zn extractions of 57.1%, 68.3% and 64.9% respectively.

The 500 g concentrate was reduced in mass to 385.4 g during the leach and the resultant residue assayed 4.19% Fe and 12.45% S. The residual iron content suggests an iron extraction of 57.8%. Table 1 shows the bioleach material balance.

CYANIDE LEACH TESTS

The results of the cyanide leach tests performed on the untreated concentrate and on the bioleach residue are provided in Tables 2 and 3. The test on the untreated head material was performed twice because of unexpected high cyanide consumption and resultant low silver recovery during the first test.

Silver balances in all three tests were good. The bioleach residue produced after 57.8% iron dissolution provided a silver extraction of 87.8%, a significant increase over the 26.8% extraction obtained from the untreated head sample. The bioleach residue still contained 875.3 grams per tonne silver. It is believed that the bulk of this silver will also be recovered when the biological treatment method has been optimized.

CONCLUSIONS

The results of these initial tests prove that the mineralization is amenable to the biological treatment process. The increase in extraction is significant, particularly if it is considered that the test was not designed to foster high extractions. To determine how well the remaining silver in the leach residue can be extracted, it will be necessary to determine in what form this residual silver is present. The tests were carried out on "as received" concentrate, but experience in biological extractions indicates that higher extraction can be obtained, as well as faster kinetics, when the concentrate is reduced in size to 90% -400 mesh.

TABLE 1

BIOLOGICAL LEACHING OF CONCENTRATE #7

PRODUCT	QUANTITY (g or mL)	ASSAY (% or g/L) Fe	S	Fe Units (g)	Distribution (%)
Head	500.0	7.06	15.8	35.30	100.0
Leach Residue	385.4	4.19	12.45	16.15	42.2
Leach Solution	5060.0	4.255		21.53	57.8
Wash Solution	960.0	0.593		0.57	
Calculated Head	500.0	7.65		38.25	100.0

TABLE 2

CYANIDATION OF CONCENTRATE #7 AND

BIOLEACH RESIDUE - MATERIAL BALANCES

	PRODUCT	QUANTITY (mL or g)	ASSAY (ppm) Au	ASSAY (ppm) Ag	UNITS (mg) Au	UNITS (mg) Ag	DISTRIBUTION (%) Au	DISTRIBUTION (%) Ag
lized	CN Head	300.0	0.206	5568.05	0.062	1670.42	100.0	100.0
	CN Solution	266.0	0	42.50	0	11.31		10.3
	Wash Solution	282.0	0	566.26	0	159.69		
	CN Residue	297.3	0.103	4991.70	0.031	1497.51		89.7
	Calc. Head	300.0		5561.7	0.031	1668.51		100.0
lized	CN Head	300.0	7.131	5490.90	2.139	1647.27	100.0	100.0
	CN Solution	277.0	0.433	827.71	0.120	229.28		26.8
at)	Wash Solution	266.0	0.225	745.13	0.060	198.20		
	CN Residue	297.2	0.103	3925.75	0.031	1166.73		73.2
	Calc. Head	300.0		5314.0	0.211	1594.21	100.0	100.0
ach	CN Head	300.0	0.720	7066.69	0.216	2120.01	100.0	100.0
ue	CN Solution	360.0	0.375	3697.73	0.135	1331.18		87.8
	Wash Solution	265.0	0	1530.71	0	405.64		
	CN Residue	274.4	0.274	875.32	0.075	240.19		12.2
	Calc. Head	300.0	0.700	6590.03	0.210	1977.01		100.0

TABLE 2

CYANIDATION OF CONCENTRATE #7 AND BIOLEACH RESIDUE - MATERIAL BALANCES

	PRODUCT	QUANTITY (mL or g)	ASSAY (ppm) Au	ASSAY (ppm) Ag	UNITS (mg) Au	UNITS (mg) Ag	DISTRIBUTION (%) Au	DISTRIBUTION (%) Ag
lized	CN Head	300.0	0.206	5568.05	0.062	1670.42	100.0	100.0
	CN Solution	266.0	0	42.50	0	11.31		10.3
	Wash Solution	282.0	0	566.26	0	159.69		
	CN Residue	297.3	0.103	4991.70	0.031	1497.51		89.7
	Calc. Head	300.0		5561.7	0.031	1668.51		100.0
lized	CN Head	300.0	7.131	5490.90	2.139	1647.27	100.0	100.0
	CN Solution	277.0	0.433	827.71	0.120	229.28		26.8
at)	Wash Solution	266.0	0.225	745.13	0.060	198.20		
	CN Residue	297.2	0.103	3925.75	0.031	1166.73		73.2
	Calc. Head	300.0		5314.0	0.211	1594.21	100.0	100.0
ach	CN Head	300.0	0.720	7066.69	0.216	2120.01	100.0	100.0
ue								
	CN Solution	360.0	0.375	3697.73	0.135	1331.18		87.8
	Wash Solution	265.0	0	1530.71	0	405.64		
	CN Residue	274.4	0.274	875.32	0.075	240.19		12.2
	Calc. Head	300.0	0.700	6590.03	0.210	1977.01		100.0

TABLE 3

CYANIDATION TESTS ON CONCENTRATE #7

AND BIOLEACH RESIDUE

		UNTREATED	UNTREATED (REPEAT)	BIOLEACH RESIDUE
Initial Weight	(g)	300.0	300.0	300.0
NaOH addition	(g)	2.73	3.25	23.90
	(kg/t)	9.10	10.83	79.66
Initial pH		11.00	11.10	11.00
NaCN addition	(g)	5.00	8.00	5.00
	(kg/t)	16.67	26.67	16.67
Excess CN	(g)	0.26	0.37	0.40
NaCN Consumption	(g)	4.76	7.63	4.60
	(kg/t)	15.87	25.43	15.33
Final pH		10.3	10.7	11.50
Final weight	(g)	297.3	297.2	274.40
Residue Assays	(g/t)			
	Au	0.103	0.103	0.274
	Ag	4991.70	3925.75	875.32
Extractions (%)	Au			
	Ag	10.3	26.8	87.8

In addition to the above the process of the present invention is applicable as a heap leaching process. As presently practiced heap leaching techniques involves spraying a cyanide solution over a heap of crushed or run of mine material to extract the gold and

silver from the ores.

Because of the poor efficiency of the cyanide treatment process for such refractory sulfide ores, as explained above, heap leaching is not in fact practiced and therefore a great quantity of the potential ores are left unmined or subjected to heap or vat leach processes which yield extractions typically of less than 70% and subject to high reagent consumption. However the process of the present invention uses bacteria to oxidize the sulfide materials and liberate the precious metals for rapid subsequent extraction. The process takes place at ambient temperature, in the range 5 to 40°C and at atmospheric pressure. In contrast to the existing high temperature processes which feature carbon dioxide gas emission the biological process converts the sulfide portion of the minerals into dilute sulfuric acid, part of which may be neutralized with lime stone as described above if necessary. Any arsenic present is oxidized and, after reacting with the ferric irons produced from the pyrite present, is converted to ferric arsenate, a waste that can be safely disposed of in a tailings pond or left in the heap.

Typically the ore to be leached will be reduced in size to approximately minus 2 inches (-8" to -½") and stacked on a heap 20 to 50 feet high. During the biological pretreatment phase of the process an acidic leach

solution containing the bacteria, typically Thiobacillus ferrooxidans, is sprayed onto the surface of the heap. The bacteria settle on the sulfide surfaces and rapidly break down the sulfide crystal structures. This liberates the precious metals from the crystals while converting the sulfide to acidic ferric sulfate and any arsenic to ferric arsenate.

Such a process may take from two to twelve months to produce the required liberation. In the second phase of the process the liberated precious metals are extracted by leaching the minerals in conventional manner, typically with a cyanide solution.

It should be noted that if a cyanide solution is used the heap must first be washed and made alkaline, that is equivalent to the step in washer 36 in the drawing, prior to cyanide extraction.

In the heap extraction process it is possible that it may be necessary to remove excess ferric iron or arsenic and in those circumstances a small partial neutralization circuit could be included where the neutralizing agent would be added in such a manner that the solution pH does not exceed 2.8. This step is equivalent to the neutralizing tank 18 in the drawing. Neutralizing in this circuit in such a manner that the pH does not exceed 2.8 forces the ferric ion to precipitate as basic ferric sulfate, a material that can be separated

readily by settling. The settled effluent can be returned to the heap leach circuit.

In the heap leach process there are a number of advantages. First it allows treatment of materials otherwise not economically treatable. The cost of a plant is a fraction of prior art concentrators and roaster smelters. Any arsenic or antimony present in the ores is converted into environmentally acceptable ferric arsenate or ferric antimonate. The bioleach process can be carried out at either very small or very large scales, entirely at the desire of the operator.

Thus the present invention provides a process able to provide extremely high yields of gold and silver by the biological extraction of these metals. Furthermore it is able to do so in materials that in many cases were not economically treatable by prior art methods. The effluents from such a process are environmentally acceptable.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A process for leaching gold and silver from sulfide bearing ores of gold and silver the method comprising:

contacting the ore with a sulfide oxidizing bacteria in a leaching suspension having a pH of not less than 0.5;

maintaining the temperature in the range 5° to 40°C;

maintaining the pH in the range about 0.5 to 2.8;

separating solids from the leaching liquid; and

extracting gold and silver from the final solids content.

2. A process as claimed in claim 1 in which sulfuric acid developed by oxidation of sulfide by the bacteria is used to maintain the pH in the defined range.

3. A method as claimed in claim 2 including neutralizing part of the sulfuric acid to maintain the pH in the desired range.

4. A method as claimed in claim 3 including removing continually part of the leaching suspension, adding to the extracted part a base to control pH then returning the removed leaching suspension to the leaching reaction.

5. A process as claimed in claim 4 in which the solids and liquids removed from the leaching suspension are separated, the solids being returned to the leaching suspension and the liquids being partially neutralized to control pH.

6. A process as claimed in claim 5 in which the partial neutralization is carried out in such a way that the pH does not rise above 2.8 causing any contained ferric iron in the leaching liquid to precipitate as basic ferric sulfate and any arsenic and antimony present in the ore, and oxidized by the ferric iron to arsenate during the biological leach, to precipitate as ferric arsenate.

7. A process as claimed in claim 1 comprising operating the process in a series of steps.

8. A process as claimed in claim 7 in which four or five steps are used.

9. A process as claimed in claim 8 in which suspension removal is carried out in the first two or three steps to control the pH.

10. A process as claimed in claim 7 in which the pH is controlled in each step to precipitate components that inhibit the bacteria.

11. A process as claimed in claim 1 in which silver and gold is removed from the final solids produced by the extraction with cyanide solution.

12. A process as claimed in claim 1 in which the sulfide oxidizing bacteria is Thiobacillus ferrooxidans.

13. A process as claimed in claim 1 carried out in a tank with agitation.

14. A process as claimed in claim 13 in which the agitation is by air sparging.

15. A process as claimed in claim 1 carried out in a heap constructed of the ore as mined, or reduced in size.

16. A process as claimed in claim 1 in which silver and gold is removed from the solids produced by extraction with cyanide, thiourea, thiosulfate, or chloride.

17. A process as claimed in claim 1 in which the ore leached contains at least one component selected from arsenopyrite, antimony sulfide and tetrahedrite.

18. A process for leaching gold and silver from sulfide bearing ores of gold and silver substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

Dated this 5th day of August, 1985.

PM MINERAL LEACHING
TECHNOLOGIES INC.
By their Patent Attorneys
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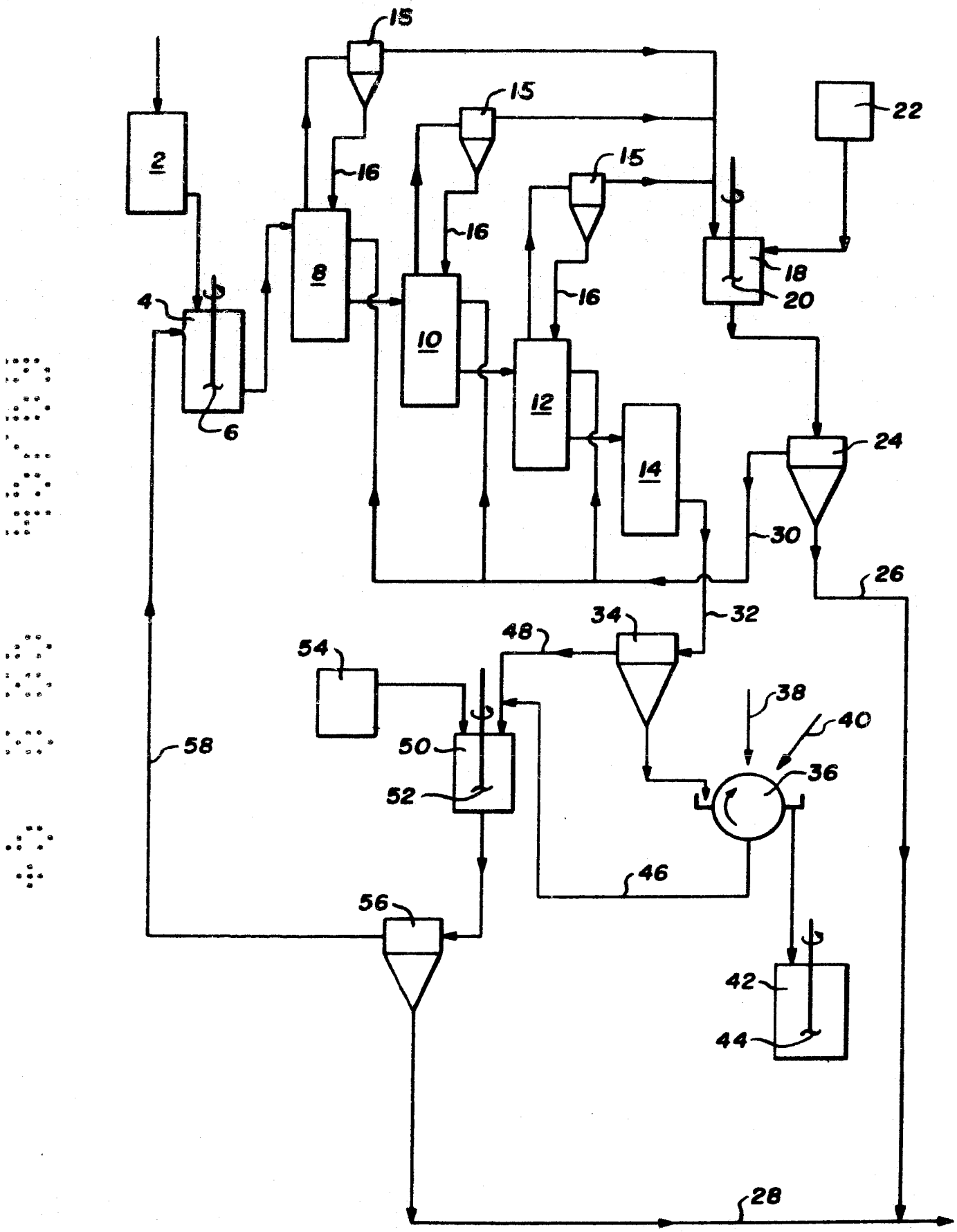
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